

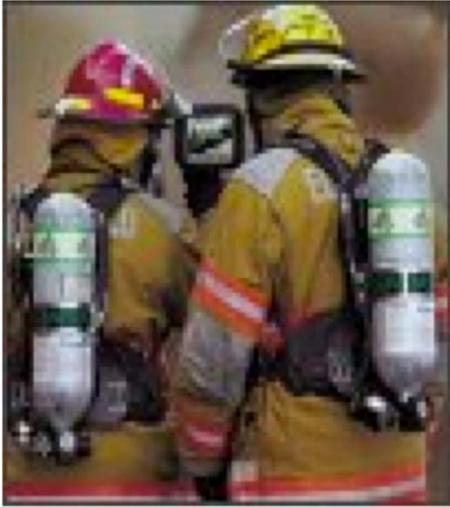


Implementation of Composite Repairs on Marine Pipelines

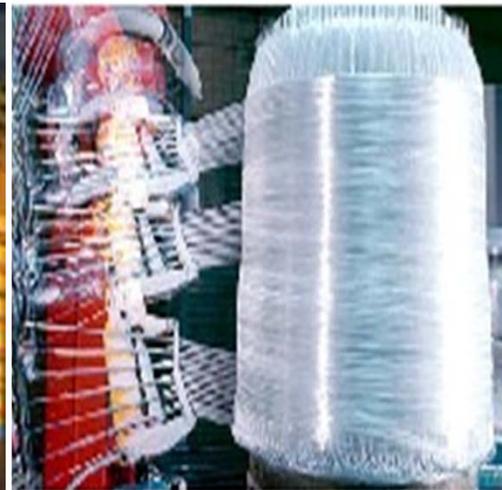
Osbaldo Chavez, Training Dept. Mgr., Technical Sales Rep.,
Clock Spring Company, L.P.

Chad Edinger, General Manager, NuStar Energy, West Region

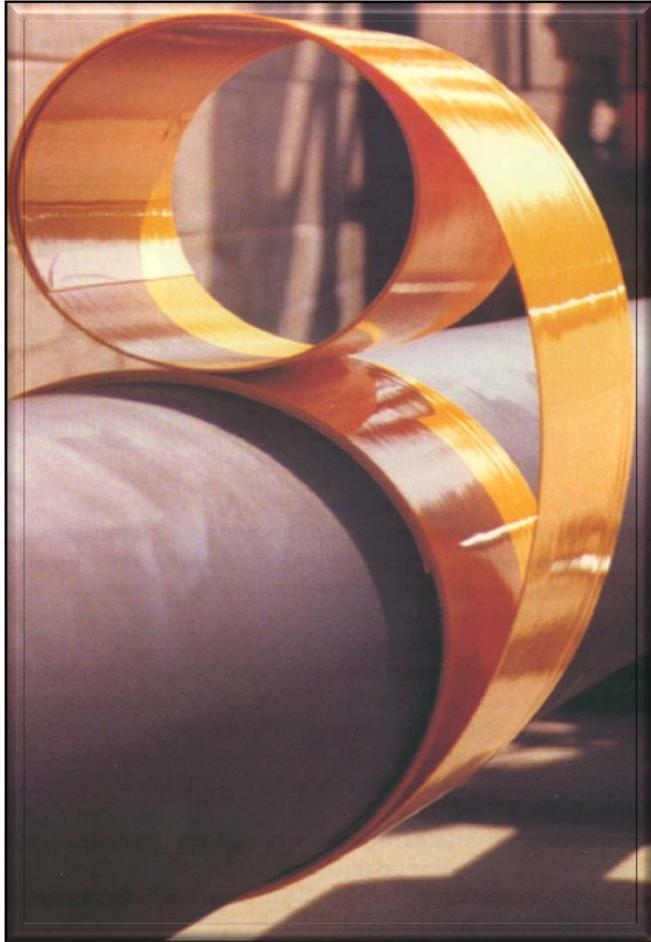
Evolution of Clock Spring®



- In 1963 Amoco pioneered the use of composites for underground storage tanks using a polyester resin/e-glass system
- In 1970's the fireman's breathing apparatus and the Natural Gas Vehicle Storage tanks were developed by NCF Industries



Composite History in Pipelines



- In 1986 NCF Industries developed Clock Spring
- Designed for arresting cracks in high pressure gas pipelines

Original Clock Spring®

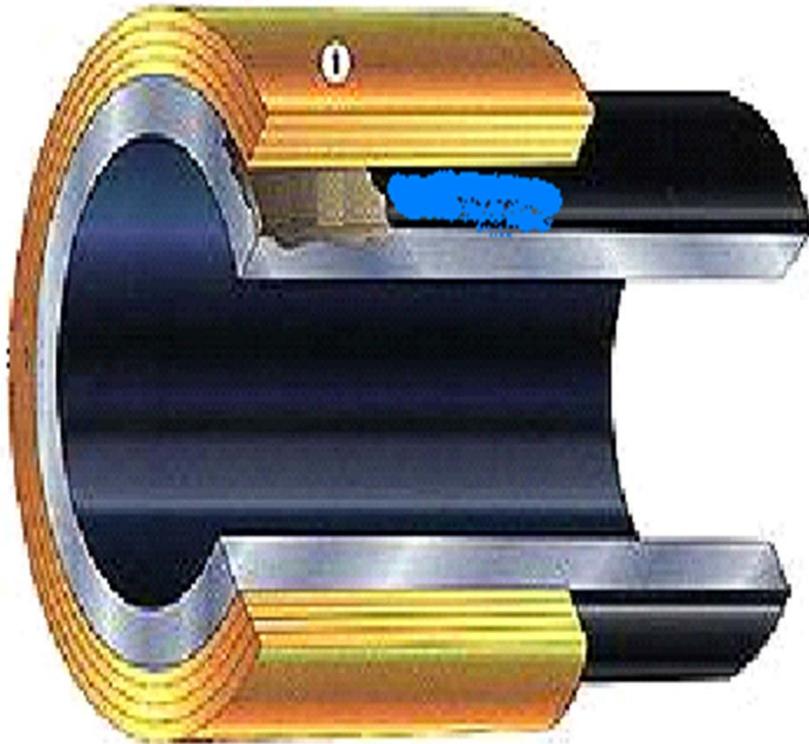
TEST 3 :

CLOCK SPRING (1-1)

Size : 1" X 6.7"

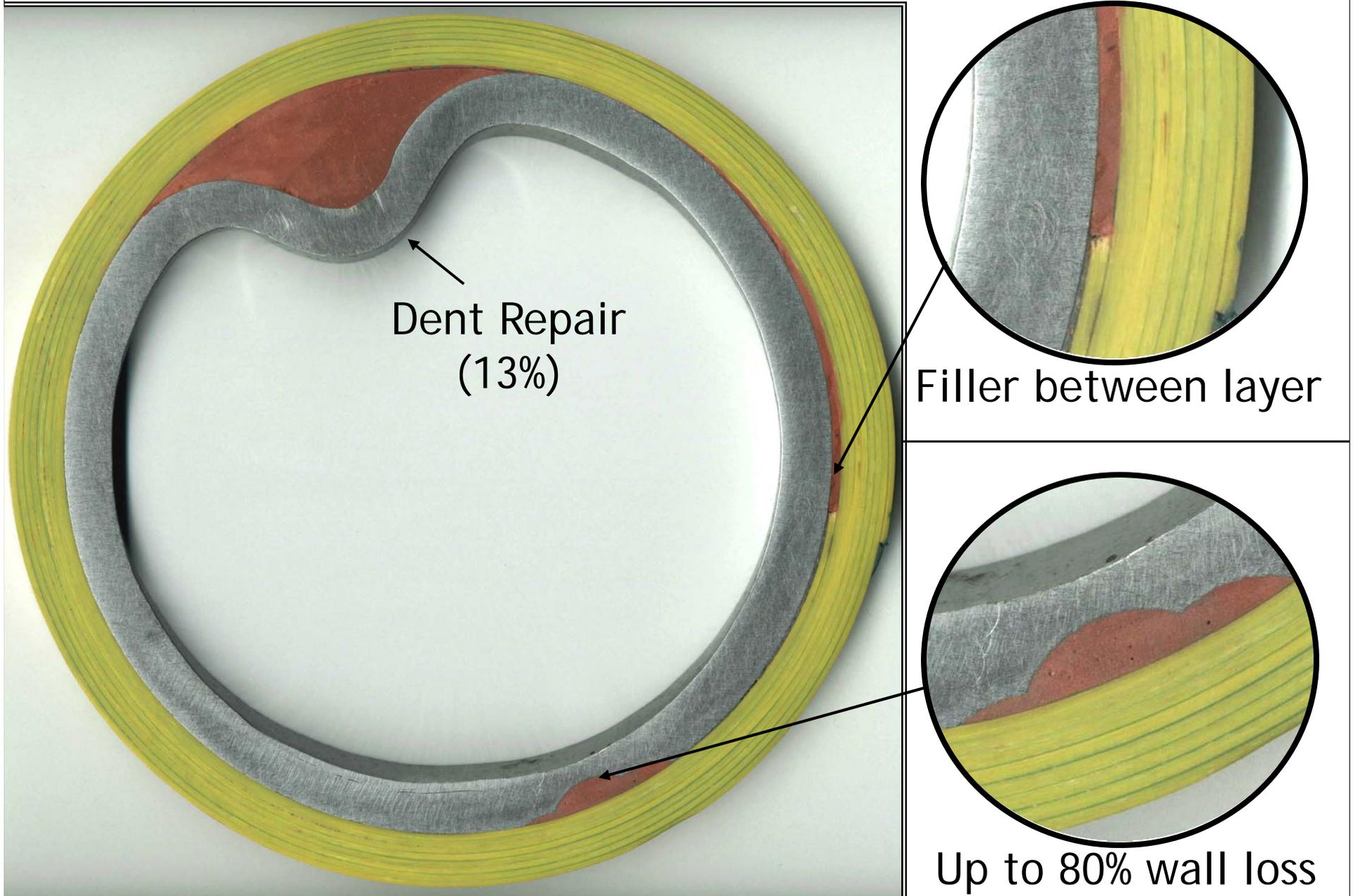
Resin Bonded

Original Clock Spring®



- ❑ Bonded In Place with Fast-Curing Methacrylate Adhesive²
- ❑ High-Modulus Filler³
- ❑ Unique Composite.
- ❑ Layers.¹
- ❑ Simple Application leads to Cost Savings and Ensures Reliability
- ❑ A composite sleeve was created

Clock Spring Cross Section (Repaired Dent and Corrosion)





GRI's Clock Spring® Program

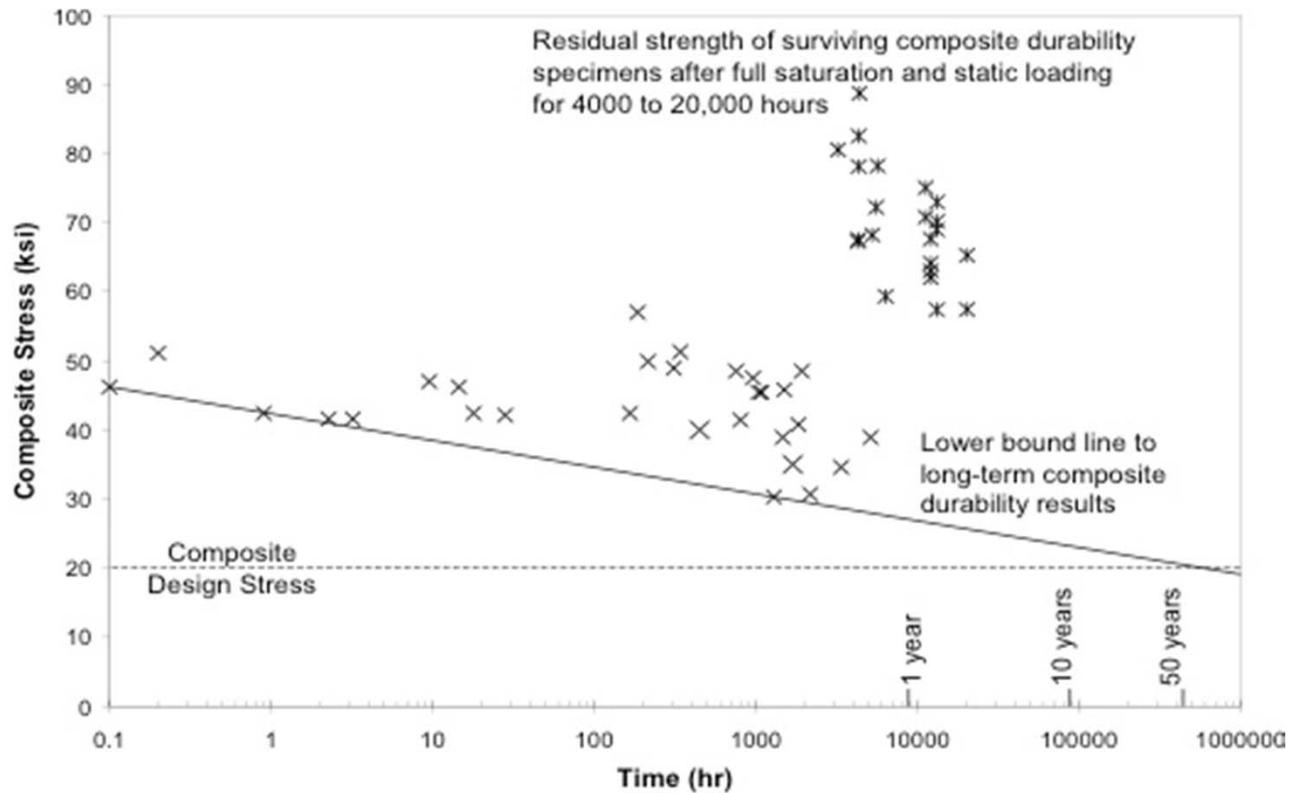
- ❑ 10-Year Research Program Started in 1987
- ❑ Goal: Find a Non-Intrusive Alternative to Steel Sleeves
- ❑ Steering Committee of Pipeline Experts from Academia & Industry
- ❑ Program Design Called for a Battery of Lab & Field Studies
- ❑ Complete Test Reports Available
- ❑ Commercially Available since 1993
- ❑ 50-Year Minimum Working Life

Sixty-Nine Units Installed



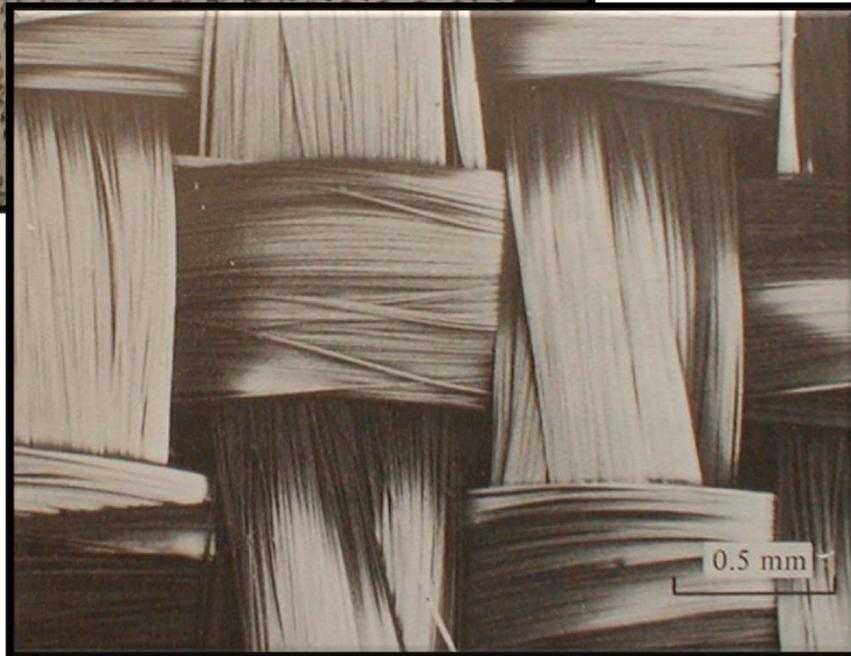
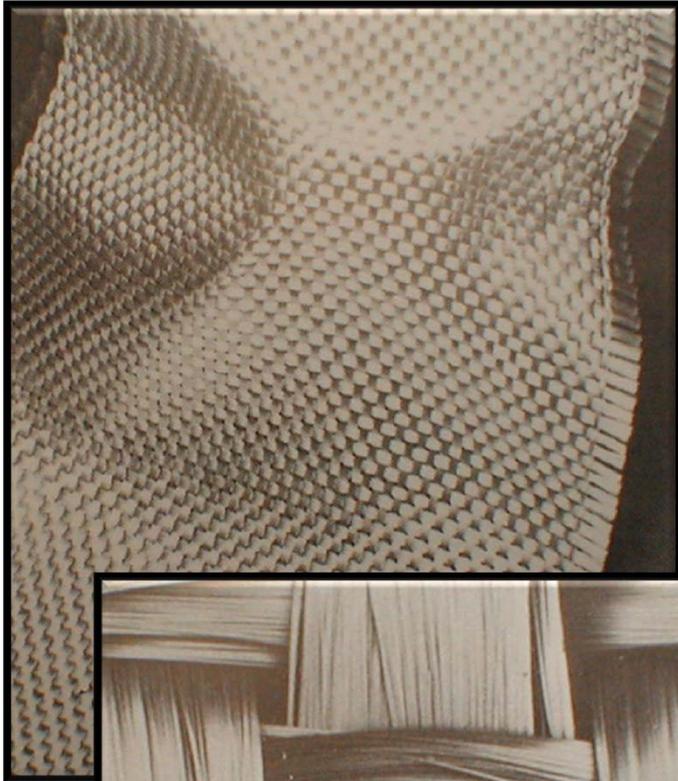
See GRI 98/0027 and GRI 98/0032 for complete reports

Stress Rupture Testing



SEE GRI 95-0071 for complete test report

Woven Cloth



- Used in the first Clock Spring®
- Only 50% of the glass is in the load direction
- Problems with cyclical loads
- Good for low pressure
- (< 500 psi) applications
- Under cyclical loads
 - Fibers move and chaff
 - Diminished strength
 - Long term performance difficult to predict

Be careful of woven cloth for reinforcement of cyclical loads.

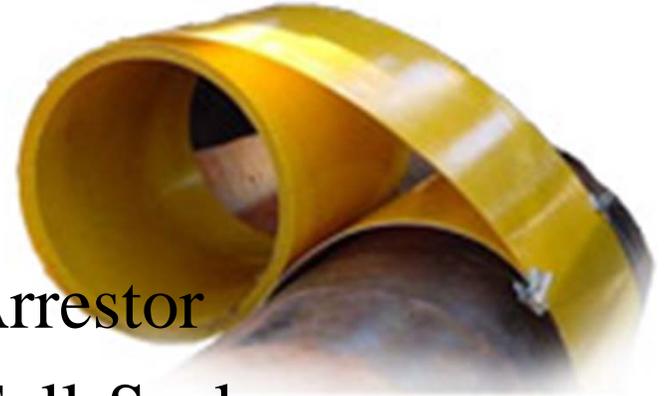
Unidirectional Glass



- ❑ Saturation of fibers is consistent
- ❑ 100% of the load carrying fibers are in the hoop direction
- ❑ Fibers will not chafe or cut one another during cyclical loading



Clock Spring® History



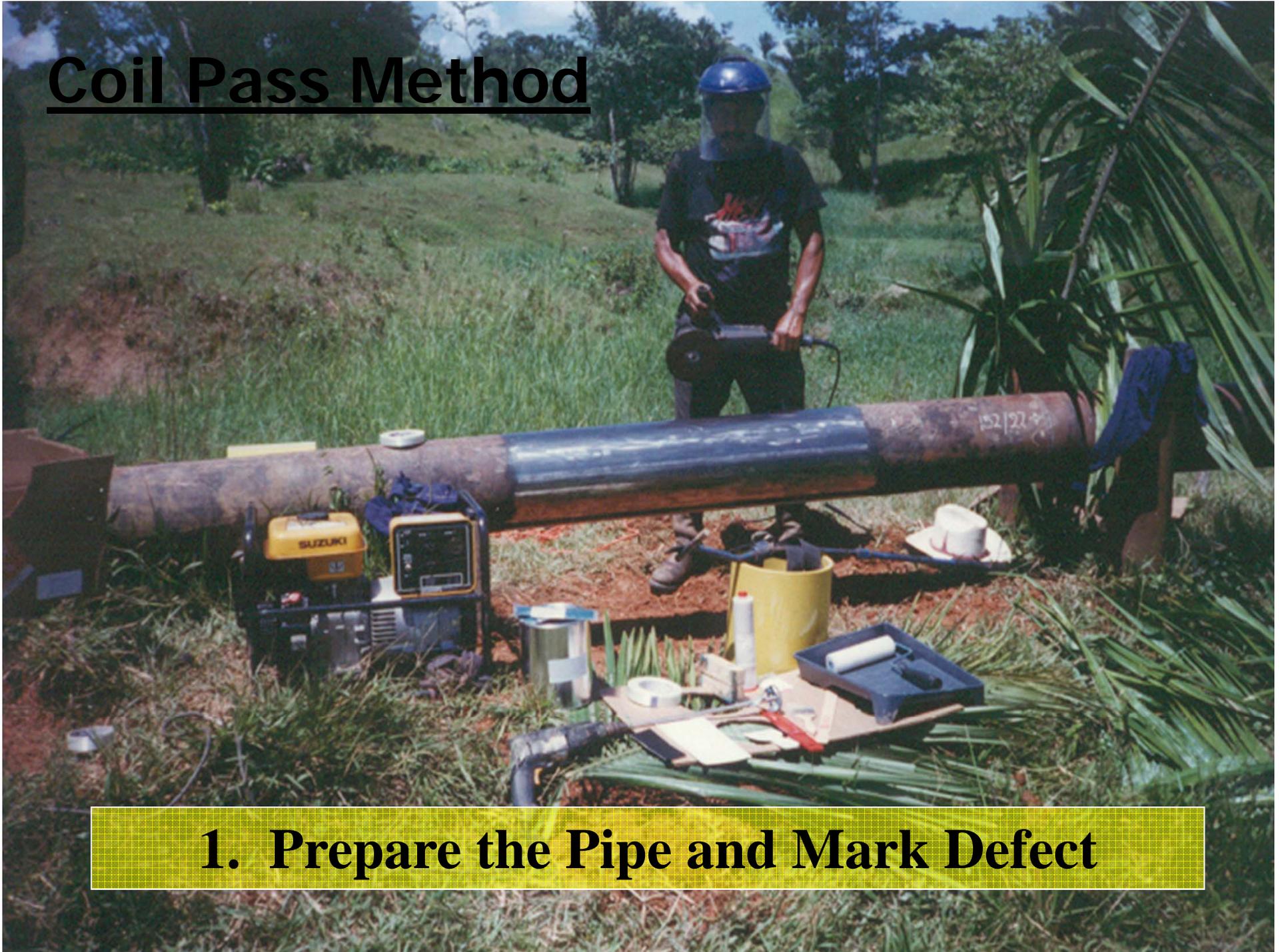
- ❑ Originally Designed as a Crack Arrestor
- ❑ Metal Loss Repairs Validated by Full-Scale Burst Tests
- ❑ Extensive R&D Reports Submitted to Regulators
- ❑ 20 Year Commercial History of Permanent Repairs
- ❑ Over 1 Million Years of Total, Cumulative Repair Service



Implementation of Composite Repairs on Marine Pipelines

Application Method

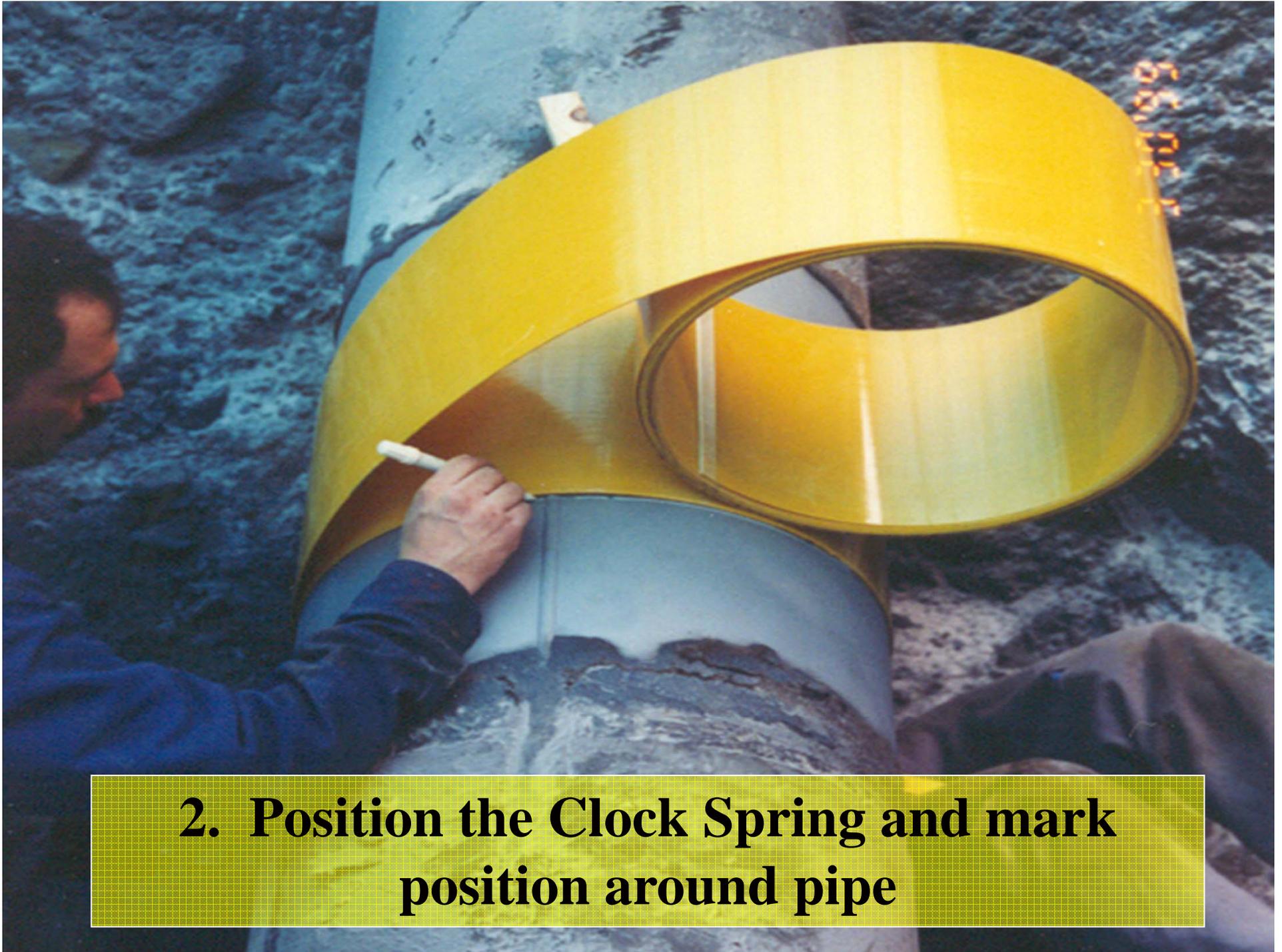
Coil Pass Method



1. Prepare the Pipe and Mark Defect







2. Position the Clock Spring and mark position around pipe



3. Mix filler and adhesive with activators



4. Install starter pad and apply filler to defects, weld seam, and starter pad area



5. Apply adhesive to Pipe Surface



6. Start passing Clock Spring around pipe



7. Apply adhesive to Clock Spring

3 30 99



8. Complete wrap and cinch tight

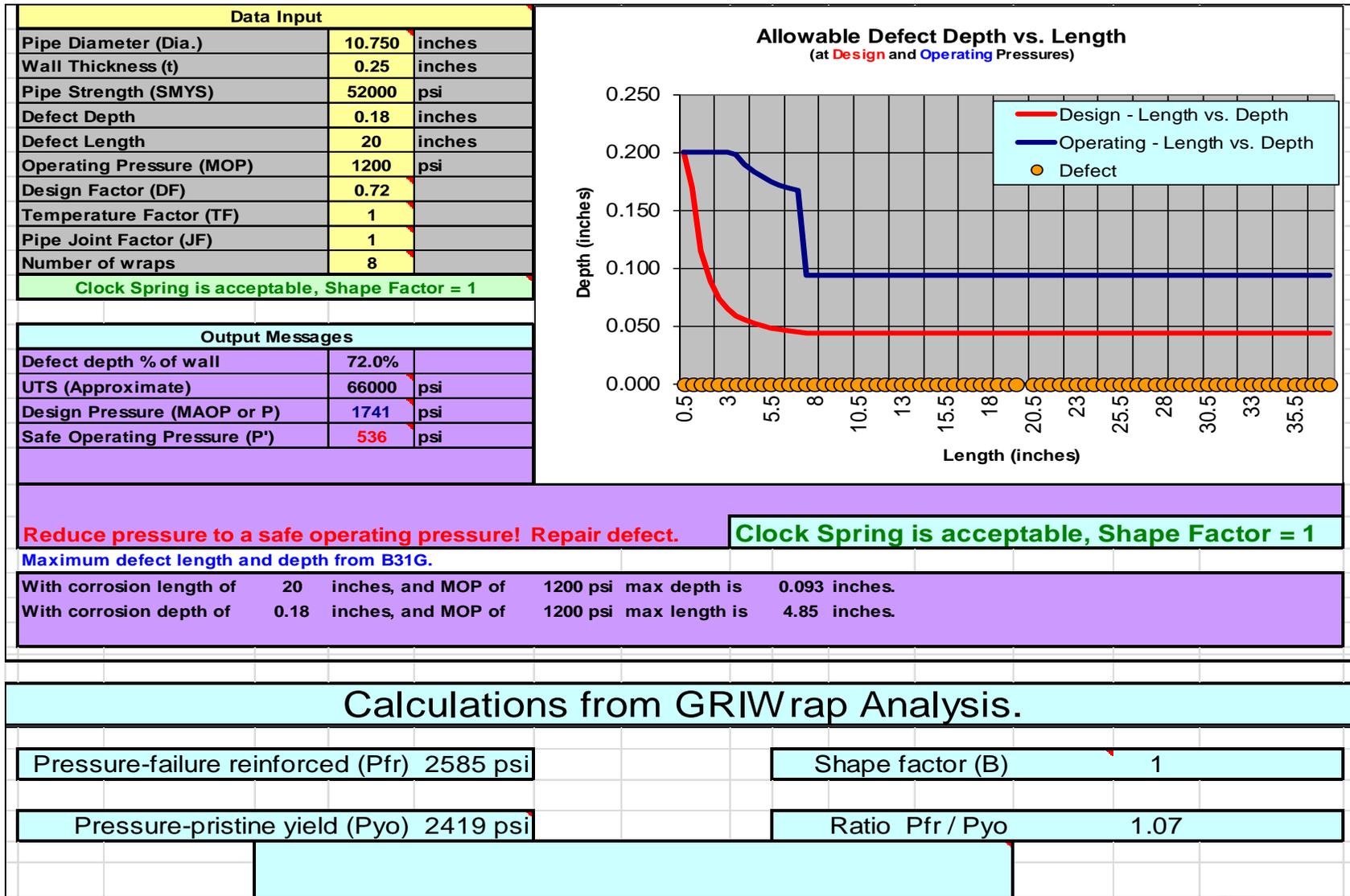


9. Wrap with filament tape, remove excess filler and seal with adhesive



**10. Re-coat and backfill - Coal Tar O.K. after Cure
(2+ hrs and 40 on a Shore A scale)**

Implementation of Composite Repairs on Marine Pipelines



Engineering Analysis - Clock Spring®

Pipe Details		Operating Details																																			
Outside diameter (Dia.)	10.75 inches	Operating pressure (Po)	1200 psi																																		
Wall thickness (t)	0.250 inches	Class Location	1	Design Factor	0.72																																
Grade (SMYS)	52000 psi	Temp.Factor (TF)	1	Joint Factor (JF)	1																																
Defect Details																																					
Defect depth	0.180 inches	Defect identification	Line # 1008																																		
Defect length	20.00 inches		Dig #2																																		
Depth as % of wall	72%	Date	October 24, 2012																																		
B31G Assessment																																					
Maximum allowable pressure (P) (MAOP)	1741 psi	$P = ((2*SMYS*t)/Dia.)*DF*TF*JF$																																			
Safe operating pressure (Ps)	536 psi																																				
At the operating pressure (Po) specified the maximum length for the depth specified is 4.850 inches.																																					
At the operating pressure (Po) specified the maximum depth for the length specified is 0.093 inches.																																					
Reduce pressure to a safe operating pressure. Repair defect.																																					
Clock Spring® Analysis																																					
Pristine yield pressure of the pipe.	2419 psi	- Pyo	$Pyo = (2*SMYS*t)/Dia.$																																		
Failure pressure of the reinforced pipe.	2585 psi	- Prf																																			
Reinforced failure to pristine yield ratio.	1.07																																				
Defect profile factor.	1																																				
Clock Spring® repair is acceptable.																																					
<table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Pressure (psi)</th> <th>Po</th> <th>Prf</th> <th>Pyo</th> <th>P (MAOP)</th> <th>Ps</th> </tr> </thead> <tbody> <tr> <td></td> <td>1200</td> <td>2585</td> <td>2419</td> <td>1741</td> <td>536</td> </tr> </tbody> </table>					Pressure (psi)	Po	Prf	Pyo	P (MAOP)	Ps		1200	2585	2419	1741	536	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="2" style="text-align: center;">Values used in calculation.</th> </tr> </thead> <tbody> <tr> <td>Failure stress of the Clock Spring®</td> <td>- 20 ksi</td> </tr> <tr> <td>Modulus of the Clock Spring®</td> <td>- 5 x 10⁶ psi</td> </tr> <tr> <td>Modulus of the pipe</td> <td>- 30 x 10⁶ psi</td> </tr> <tr> <td>Wrap thickness</td> <td>- 0.0625 inches.</td> </tr> <tr> <td>Number of wraps</td> <td>- 8</td> </tr> <tr> <td>Thickness of repair</td> <td>- 0.500 inches</td> </tr> <tr> <td>Defect circumferential extent</td> <td>- 100%</td> </tr> <tr> <td colspan="2"> Po - Operating pressure. Prf - Reinforced failure pressure. Pyo - Pristine yield pressure. P - Design pressure (MAOP) Ps - Safe operating pressure (B31G). </td> </tr> <tr> <td colspan="2" style="text-align: right;">Version 120302</td> </tr> </tbody> </table>	Values used in calculation.		Failure stress of the Clock Spring®	- 20 ksi	Modulus of the Clock Spring®	- 5 x 10 ⁶ psi	Modulus of the pipe	- 30 x 10 ⁶ psi	Wrap thickness	- 0.0625 inches.	Number of wraps	- 8	Thickness of repair	- 0.500 inches	Defect circumferential extent	- 100%	Po - Operating pressure. Prf - Reinforced failure pressure. Pyo - Pristine yield pressure. P - Design pressure (MAOP) Ps - Safe operating pressure (B31G).		Version 120302	
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Implementation of Composite Repairs on Marine Pipelines

□ Case Study One-NuStar Terminal Overview





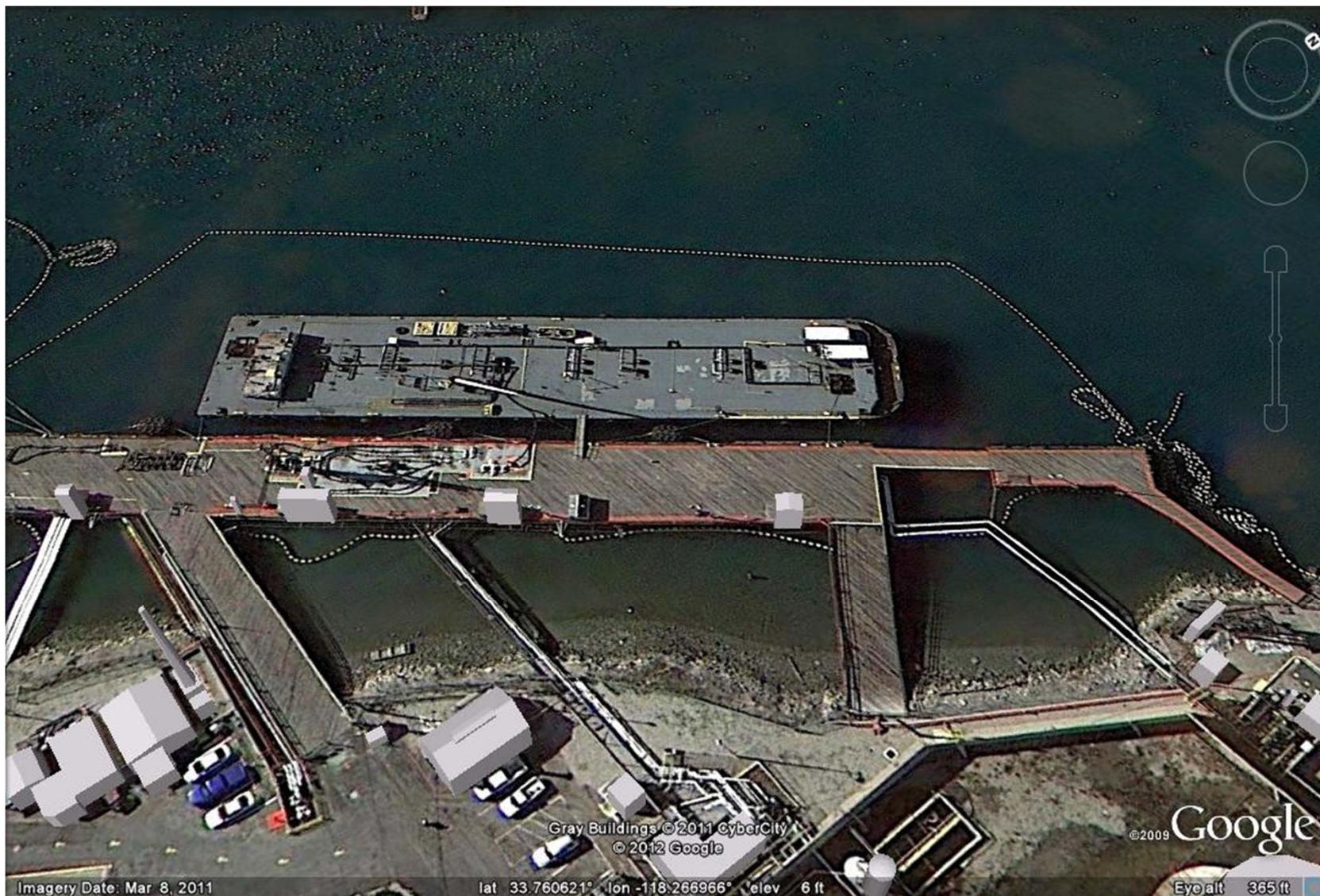
Implementation of Composite Repairs on Marine Pipelines

□ Terminal Overview

- Port of Los Angeles-NuStar Energy Terminal
 - 607,000 bbls of storage capacity
 - Marine receipt/delivery across multiple 6, 8, 10, 12 inch dock pipelines
 - Multiple product grades handled and isolated by line for product quality purposes
 - Facility handles ~30 barges or vessels per month
 - Wharf downtime of any kind would become critical path to customer base
 - Wharf and associated piping are slated to be significantly modified as a result of MOTEMS seismic evaluation
 - Repair strategy utilized established corrosion rates to allow for a safe amount of remaining thickness; considering the useful life of the wharf



Implementation of Composite Repairs on Marine Pipelines





Implementation of Composite Repairs on Marine Pipelines

❑ Challenging Maintenance Scenario

- Regulatory inspection requirements and associated repair strategies
 - Pipes suspended beneath the decking of a timber pile structure via full encirclement split clamp hung with all-thread from timbers
 - Access to repair sites can be challenging due access through timber cross-members depending on changing tidal conditions
- API 570, API 2611, DOT, PSM Process Piping Inspection/Repair Criteria
 - Depending on regulatory driver or repair strategy, the requisite training/application requirements for installer and the qualifications for that installation may be critical path to complete in a timely manner
 - DOT involvement and Operator Qualifications
 - Approved contractors based on company policy
 - Availability of capable and qualified contractors



Implementation of Composite Repairs on Marine Pipelines





Implementation of Composite Repairs on Marine Pipelines





Implementation of Composite Repairs on Marine Pipelines





Implementation of Composite Repairs on Marine Pipelines

□ Recent Example at NuStar Terminal

- API 570 inspection revealed areas of significant external corrosion on uncoated pipe with as little as .10” remaining thickness
- Based on established corrosion rates, some areas only required external coating to mitigate future corrosion
- Areas under pipe clamps were unknown and were not able to be inspected with UT
 - Pipe to clamp areas were known not to have a non-conductive material between pipe and steel support
 - Dissimilar metals creates a known corrosion cell in the marine environment where moisture is trapped
 - These areas were treated as unknowns and were to be inspected separately with the proper precautions

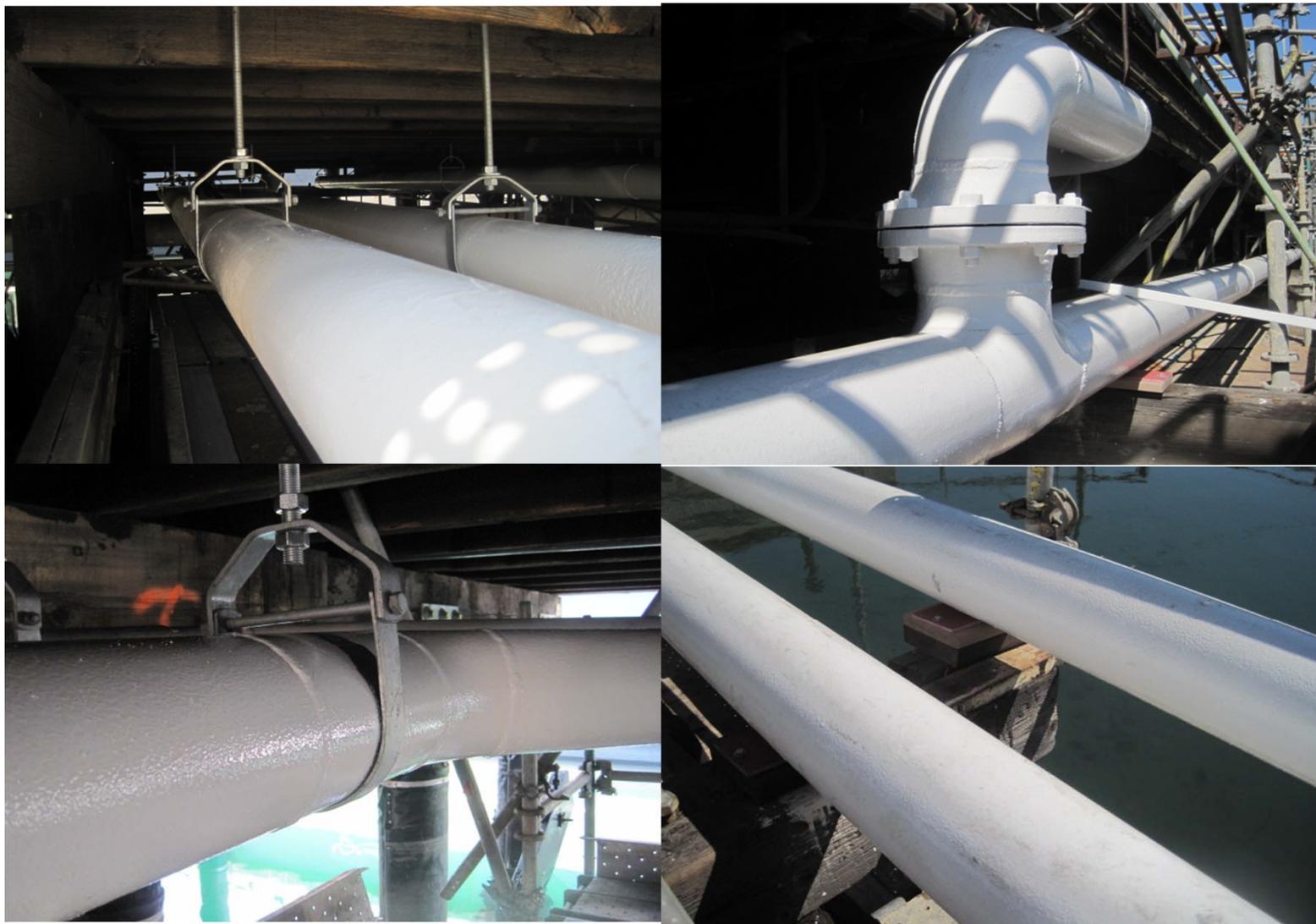


Implementation of Composite Repairs on Marine Pipelines

- ❑ Two Part Strategy to exposed pipe repair
 - Depending on site-specific corrosion, either prep and externally coat, or
 - In the areas of exposed piping (away from pipe supports), “Snap-Wrap” Clockspring© materials were chosen as final mitigations
- ❑ Majority of piping had majority of original thickness and could be coating as the full mitigation
- ❑ Isolated areas required clockspring repairs; generally as a result of improper support-to-pipe buffer material
 - Generally in areas of trapped water to pipe
 - Dissimilar metal to metal contact



Implementation of Composite Repairs on Marine Pipelines





Implementation of Composite Repairs on Marine Pipelines

❑ Pipe Support Repair Strategy

- Original plan was to support, remove clamps, UT, then repair similar to the exposed pipe depending on the RT under the pipe support
- No evidence or history of leak or weep on the pipe or support
- Alternative was to construct new transfer line and to demo existing.





Implementation of Composite Repairs on Marine Pipelines

- ❑ Why we choose non-metallic repairs versus full-encirclement sleeves?
 - Hot work-need to de-product the line and risk to the surrounding environment
 - Prep work for sleeves includes significant downtime
 - The finished product with non-metallic repair has built-in corrosion resistance
 - Biggest issue-spill risk if breaking flanges torching, cutting
 - Time line is considerably shorter
 - Finished product has equal strength & integrity as original pipe



Implementation of Composite Repairs on Marine Pipelines

Product Options Available

CLOCK SPRING®

Snap Wrap



Low Pressure Pipe Repair - up to
500psi



Clock Spring® Snap Wrap

- ❑ Pre-Fabricated Bi-Directional Sleeves 3/4" to 56"
- ❑ 4 Layer System
- ❑ 3" minimal clearance is required
- ❑ Up to 90% Wall Loss
- ❑ 2hr Cure Time on Adhesive

Crevice Corrosion



CLOCK SPRING®

Pipe Support



□ 360° Protection at Contact Points

Clock Spring® Pipe Support

- ❑ Pre-Fabricated Bi-Directional Sleeves from 3/4" to 56"
- ❑ 3 Layer System
- ❑ Bonded 360° for Protection at Contact Points
- ❑ 2hr Cure Time on Adhesive



Clock Spring® Pipe Support



- ❑ Corrosion is a Leading Cause of Piping Failures
- ❑ Water Entrapment, Disbondment, Coating Failure
- ❑ 360° Encirclement by Clock Spring® Pipe Support offers Maximum Protection at Contact Points
- ❑ Design Works with Virtually Any Support Type
- ❑ Fast, Easy Installation

Application



CLOCK SPRING®

CONTOUR



Pipe Repair - up to 1000 psi.

CONTOUR®

- Wet Lay Up System 1" to 36"
 - Repairs: Straight Pipe, Tees, Bends & Flanges
- Up to 1000psi on corrosion type defects
- Leaks are temporary – up to 350psi
- 6-10hr Cure Time on Oil Base Epoxy

Contour



Elbows & Connections

Contour



Bends & Reducer



Tees



Clock Spring® Today

- Clock Spring began Commercial Operations in 1993
- Today: Sales in Over 75 Countries
- Over 1 Million Years of Cumulative Repair Service
- Clock Spring is Successful Because:
 - Technically Sound Product
 - Economically Advantageous
 - Trouble-Free





Implementation of Composite Repairs on Marine Pipelines

Questions?

Chad.Edinger@nustarenergy.com

Ochavez@Clockspring.com